

# THE MARS ENVIRONMENTAL SURVEY (MESUR) NETWORK AND PATHFINDER MISSIONS

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## Abstract

The objective of the Mars Environmental Survey (MESUR) Network mission is to establish a global network of small science stations on the surface of Mars to operate concurrently over a minimum of one martian year. MESUR Network is viewed as an evolutionary and affordable step in the scientific characterization of the martian environment following Viking and Mars Observer and preceding sample return and human exploration missions. The full network is envisioned to consist of an international complement of 16 or more landers providing pole-to-pole coverage of the planet. The broad science objectives of the MESUR Network mission are to characterize the martian environment in terms of atmospheric structure, internal structure, global atmospheric circulation, surface chemistry, and surface morphology. The strawman science payload for the Network mission includes an atmospheric structure package (pressure, temperature, and acceleration measurements during descent), cameras for descent and surface imaging, 3-axis seismometer, meteorology package, Alpha/Proton/X-Ray Spectrometer, Thermal Analyzer/Involved Gas Analyzer, radio science experiments, and others. The MESUR Network project start is targeted for FY1996 with the first launch occurring no earlier than the 1998/99 opportunity.

A precursor to the MESUR Network mission, designated MESUR Pathfinder, is targeted for an

FY 1994 project start. The objective of the Pathfinder mission is to conduct the engineering demonstrations required prior to the full commitment of funds to develop and proceed with the MESUR Network mission. The primary engineering test performed by Pathfinder will be of an entry, descent, and landing approach which employs an aeroshell, parachute, solid tractor rocket, air bags, and a lander/petal system. This entry, descent, and landing system is required to decelerate the vehicle from high entry velocity, achieve a semi-hard landing on the martian surface, and establish an upright configuration for the surface operational phase of the mission.

## Introduction: Evolution of MESUR

In 1978, the National Academy of Science's Committee on Planetary and Lunar Exploration (COMPLEX) provided direction to the post-Viking Mars exploration program in stating:

"The primary objectives in order of scientific priority for the continued exploration of Mars are:

### (1) The intensive study of local areas:

- (a) To establish the chemical, mineralogical, and petrological character of different components of the surface material, representative of the known diversity of the planet;
- (b) To establish the nature and chronology of the major surface forming processes;
- (c) To determine the distribution, abundance, and sources and sinks of volatile materials, including an assessment of the biological potential of the martian environment, now and during past epochs;
- (d) To establish the interaction of the surface material with the atmosphere and its radiation environment;

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- (2) To explore the structure and general circulation of the martian atmosphere;
- (3) To explore the structure and dynamics of Mars' interior;
- (4) To establish the nature of the martian magnetic field and the character of the upper atmosphere and its interaction with the solar wind;
- (5) To establish the global chemical and physical characteristics of the martian surface." [1]

in 1983, the Solar System Exploration Committee of the NASA Advisory Council recognized that the degree to which Mars science objectives could be accomplished depended on the establishment and operation of a network of long-lived science stations at diverse locations on the surface of Mars to perform seismic, meteorological, and geoscience observations [2]. Various concepts to establish a global Mars landed network were studied as part of the so-called "90 Day Study" [3]. In 1991, the NASA Ames Research Center developed an innovative concept for a Mars Environmental Survey (MESUR) mission that involved the phased emplacement of a 16-lander network on Mars beginning with the first launch in the 1998/1999 opportunity and ending in 2006 after one Mars year (1.8 Earth years) of full network concurrent operations [4].

Responsibility for the Phase A study of the MESUR Network mission was assigned to the Jet Propulsion Laboratory (JPL) in November of 1991. In early 1992, JPL was directed to study the feasibility of launching a MESUR Network precursor mission under tight schedule and cost constraints to demonstrate engineering systems and technologies key to the Network. The precursor mission, designated MESUR Pathfinder, is slated for a new start as the first Discovery class mission in October 1994 with a launch in late 1996. The MESUR Network start is targeted for 1996 with the first launch targeted for no earlier than the 1998/99 opportunity.

### MESUR Network

The broad science objectives of the Network mission are to characterize the environment of Mars in terms of the internal structure of the planet, the global atmospheric circulation, the structure of the

upper atmosphere, surface morphology, geochemistry, and the elemental composition of rocks [4]. The strawman instrument payload designed to accomplish these objectives include:

#### Three-axis seismometer

The Network seismometer measures ground motion with high sensitivity, large dynamic range, and large bandwidth. The seismometer requires a deployment mechanism to emplace the instrument in direct contact with the soil a few meters from the lander. The data volume associated with the seismology investigation is estimated at 10 megabits per day per lander after event triggering logic and data compression algorithms are employed. The data volume associated with the seismology investigation is a significant mission driver to develop a high capacity direct-to-Earth downlink or to deploy a Mars Relay Satellite (MRS). In addition, the seismology investigation requires instrument operations over a significant period of time (one Mars year baselined) to insure a high probability that Marsquakes are detected.

#### Meteorology instruments

The full meteorology experiment is designed to perform high frequency surface pressure, temperature, wind velocity, humidity, and atmospheric opacity measurements. The baseline meteorology investigation requires a pole-to-pole emplacement of landers and instrument operations over a minimum of one Mars year. Landers placed at latitudes greater than  $\pm 45^\circ$  cannot rely on solar power for operations during all seasons. The "n-ini-Met" lander concept was devised to allow the year-round acquisition of high priority meteorology data at high latitudes. The n-ini-Met lander is powered either by a primary battery or a "power stick" which is a standard Radio-Isotope Heater (RHU) unit attached to a thermocouple. The power provided by the primary battery or power stick is sufficient to provide hourly measurements of pressure, temperature, and opacity and allow the transmission of these data to a relay satellite or directly to Earth (at low data rates).

#### Alpha/Proton/X-Ray (APX) Spectrometer

The APX spectrometer measures the elemental composition of surface soil and rocks for most major elements except hydrogen. The spectrometer must be placed in direct contact with the soil and

rock samples to obtain a measurement. Thus, a surface rover, mechanized arm, or other deployment mechanism is required.

#### Thermal Analyzer/Evolved Gas Analyzer (TA/EGA)

The TA/EGA determines the mineralogical composition of the martian soil. A soil sample is placed in an oven, heated, and changes in heating and gas releases are monitored. The gas analyzer measures the water, carbon, nitrogen, oxygen, organic, and oxidant content of the released gas. A mechanism is required for obtaining samples.

#### Descent Imager

The descent imager obtains nested images of the martian surface during the parachute descent. These images are used to establish the geologic context of the science measurements taken by the landed station.

#### Surface Imager

The multiband surface imager provides a 360° panorama from the lander edge to the horizon in order to determine the surface characteristics of the landing site.

#### Atmospheric Structure instrument (ASI)

The ASI obtains pressure and temperature profiles of the martian atmosphere along the entry vehicle trajectory to the surface. In addition, an atmospheric density profile is derived from 3-axis acceleration measurements taken during entry and descent.

#### Radio Science

Simultaneous 2-way coherent Doppler tracking of three (or more) landers from a single Earth antenna once per week for one Mars year provides information which yields decimeter level determination of Mars rotational parameters.

Satisfaction of the MESUR science objectives requires the concurrent operation of multiple landed stations for an extended period of time (nominally one Mars year). The original scenario for the emplacement of the Network involved a phased deployment over three launch opportunities due to anticipated annual funding rate constraints,

Specifically, a single Delta 11 (7925) launch in 1999 would inject four free-flying aerocraft on a trans-Mars trajectory. Two Delta launches in 2001 would deploy four additional aerocraft and a single communications relay orbiter to Mars. Finally, two Delta launches in 2003 would deploy eight aerocraft to complete the 16 lander Network. Operations of the landed stations would continue for a minimum of one Mars year after the arrival of the final complement of eight landers. Thus, a surface lifetime in excess of 6 Earth years is required by the four landers launched in 1999 to satisfy the one Mars year concurrent Network operations requirement.

The current budget climate, as well as technical issues such as the extended surface lifetime requirement of the landed stations, have led to the decision to revisit the MESUR Network design. The MESUR Project Team at JPL, the Mars Science Working Group, the MESUR Science Definition Team, the International Mars Exploration Working Group, and others are studying alternative mission architectures and vehicle designs. In addition, on August 6, 1993, JPL announced the selection of Hughes Aircraft Company and Rockwell International Corporation as the two associate contractors for the MESUR Network Phase B1 study and MESUR Pathfinder support effort. During Phase B1, scheduled to begin in November 1993, each of the two contractors will support NASA and JPL in defining the MESUR Network architecture and future implementation plans. The overall goal of the redesign effort is to utilize innovative designs and international cooperation to define an affordable Network mission in terms of both development and total mission life cycle costs that accomplishes the major science objectives of the Mars exploration program. Trade issues which have major cost and science impacts and are an integral part of the redesign effort have been identified as follows:

#### Science

- Number of landers
- latitude dispersion of landers
- Science, instrument suite
- instrument deployment scheme

#### Power

- Radioisotope Thermoelectric Generators (RTG's) vs. solar powered landers

### Communications

- Direct-to-Earth downlink vs. Communications relay orbiter(s)

### Thermal Control

- RTG vs. Radioisotope Heating Unit (RHU) + solar vs. Phase Change Material (PCM) + solar

### Launch Vehicles

- Delta, Taurus, Atlas, Titan, Ariane, Proton, etc.

### Surface Life

- 1 month vs. 1 Mars year vs. multiple Mars years

### Deployment

- Full vs. phased Network emplacement
- Cruise carrier vs. Free-flier

### Hardware

- Common landers vs. landers based on focused surface function
- Integrated landers vs. landers based on available hardware
- Redundancy vs. single string

The near term schedule for the Network architecture re-definition effort includes a MESUR Science Definition Team Meeting in September, 1993, a meeting of the international Mars Exploration Working Group in Graz, Austria, in October, 1993, and the initiation of the MESUR Network Phase B1 study in November, 1993.

### MESUR Pathfinder

As part of the MESUR program, JPL is studying the feasibility of landing a single vehicle on Mars in 1997 as a demonstration of the enabling systems, technologies, and management approaches for the MESUR Network mission. Because the planned Network mission will have a different, more stressful landing procedure than was used by Viking, it is important to demonstrate critical entry, descent, and safe landing functions prior to the full-up implementation of the MESUR Network fabrication activity. The demonstration mission, designated MESUR Pathfinder, is the first of the Discovery class missions. Discovery missions are defined as fast schedule (3 year development cycle), low cost (\$150 million development cost cap) missions with significant, but focused, science objectives.

The primary objective of MESUR Pathfinder is to demonstrate critical functions, particularly the entry, descent, and landing function, required for the successful development and deployment of the MESUR Network stations. Scientific objectives and the instrument payload for Pathfinder include:

- Acquisition of atmospheric structure data along the Pathfinder entry trajectory from an entry instrument package (pressure, temperature, and vehicle acceleration),
- Characterization of surface morphology and geology at meter scale from a surface imaging camera,
- Determination of the elemental composition of rocks and/or surface materials from alpha/proton/X-ray spectrometer measurements.

A single MESUR Pathfinder aircraft will be launched on a Delta class launch vehicle in December/January 1996. The Pathfinder aircraft consists of a cruise stage, aeroshell (heat shield and back cover), decelerator systems (parachute, solid retrorocket, and air bags), and a lander as shown in Figure 1. The aircraft will be spin-stabilized and Earth-pointed during the cruise to Mars. Pathfinder will enter the martian atmosphere on July 4, 1997 directly from the hyperbolic transfer orbit and descend to the surface using the aeroshell, parachute, and solid retrorocket to slow the descent and an air bag system to attenuate the landing shocks as shown in Figure 2. The Pathfinder landing site will be selected from available low elevation areas large enough to accommodate anticipated targeting dispersions near the sub-solar point at 15° North latitude. Landing sites near 15° North latitude provide good solar and Earth visibility conditions for the primary solar power and direct-to-Earth communications for the duration of the Pathfinder 30 day primary mission. A free-ranging, solar powered rover surface vehicle, developed with NASA Code C funding, will be flown on Pathfinder. The rover, as shown in Figure 3, will be deployed from the lander to conduct rover technology experiments, determine the viability of rover operations in the martian environment, and to serve as deployment platform for the alpha/proton/X-ray spectrometer. The acquisition and return of scientific data and rover operations will commence immediately following the playback of key engineering data regarding the condition and

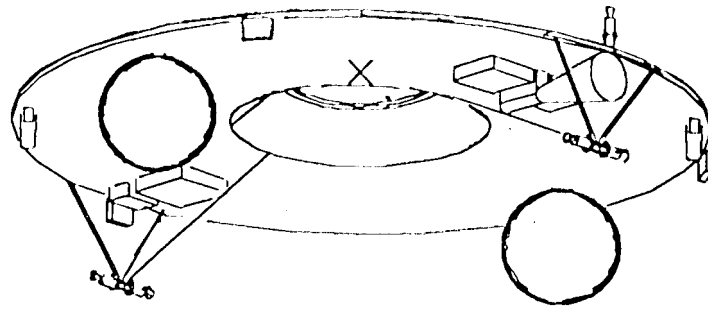
configuration of the lander and the characteristics of the entry, Figure 4 provides an artists conception of the MESUR Pathfinder lander and deployed rover on the surface of Mars.

#### Acknowledgment

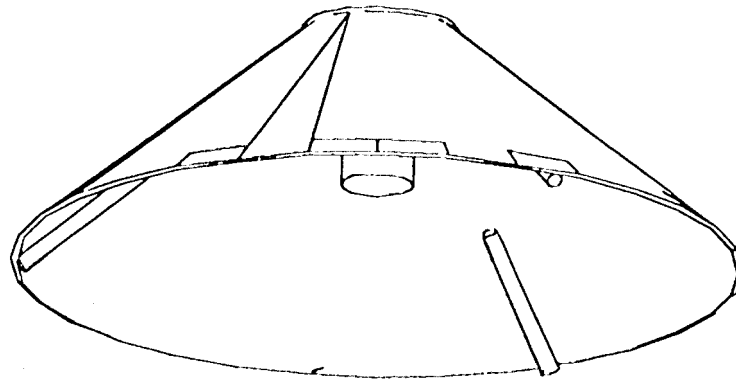
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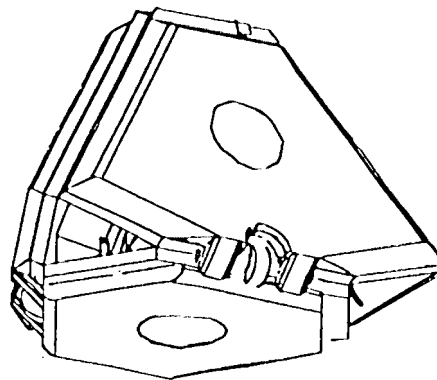
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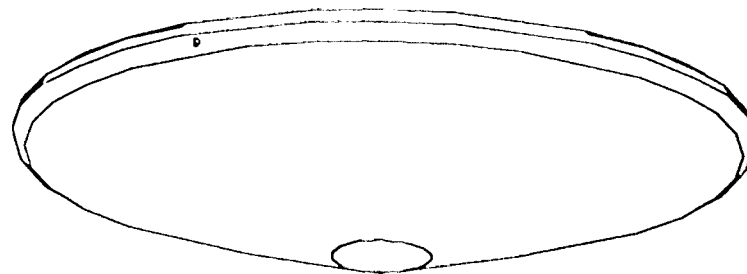
Cruise Stage



Backshell



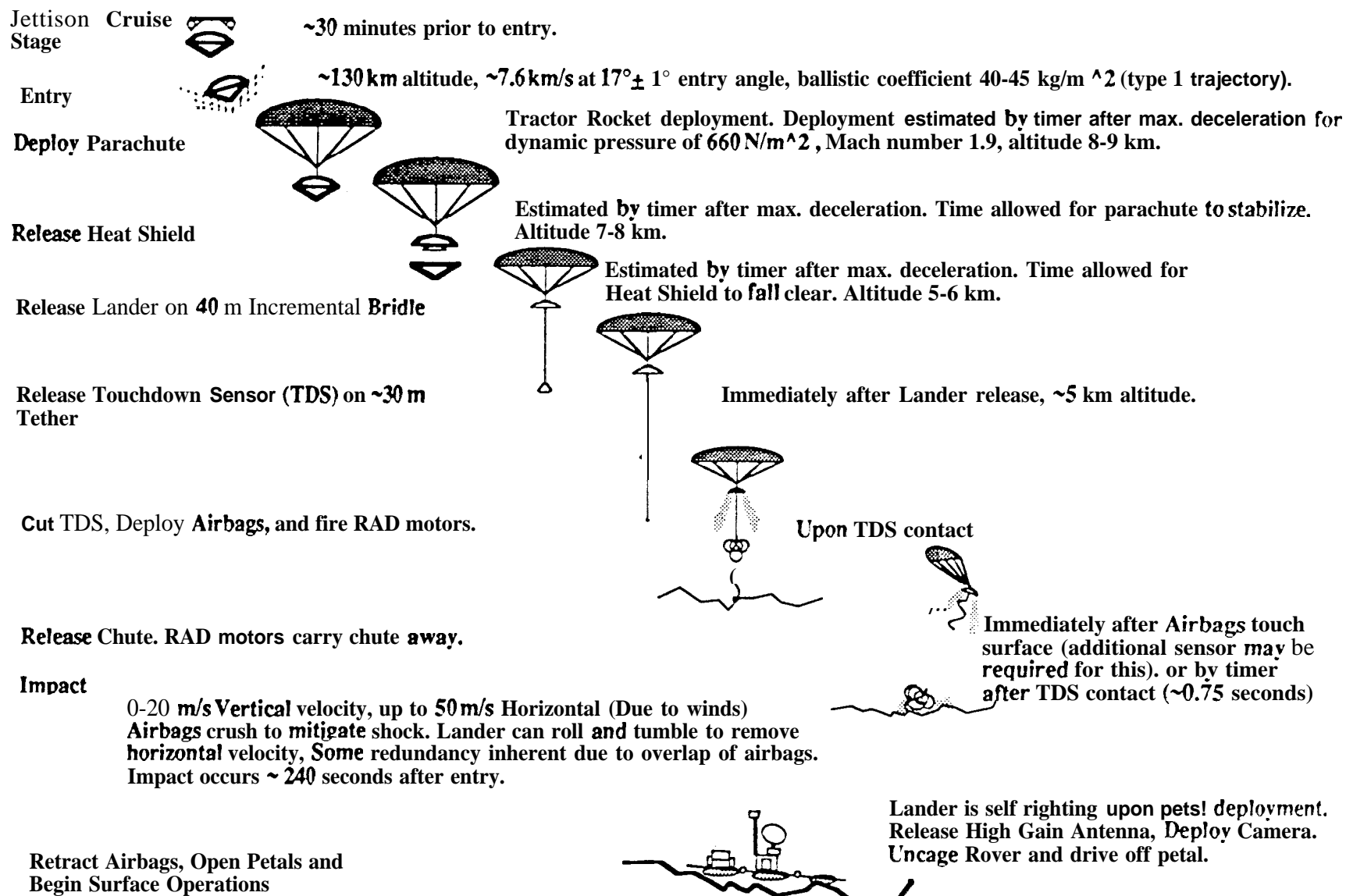
Lander



Heatshield

Figure 1. Exploded View of MESUR Pathfinder Flight System

Figure 2. MESUR Pathfinder Entry, Descent, and Landing Scenario



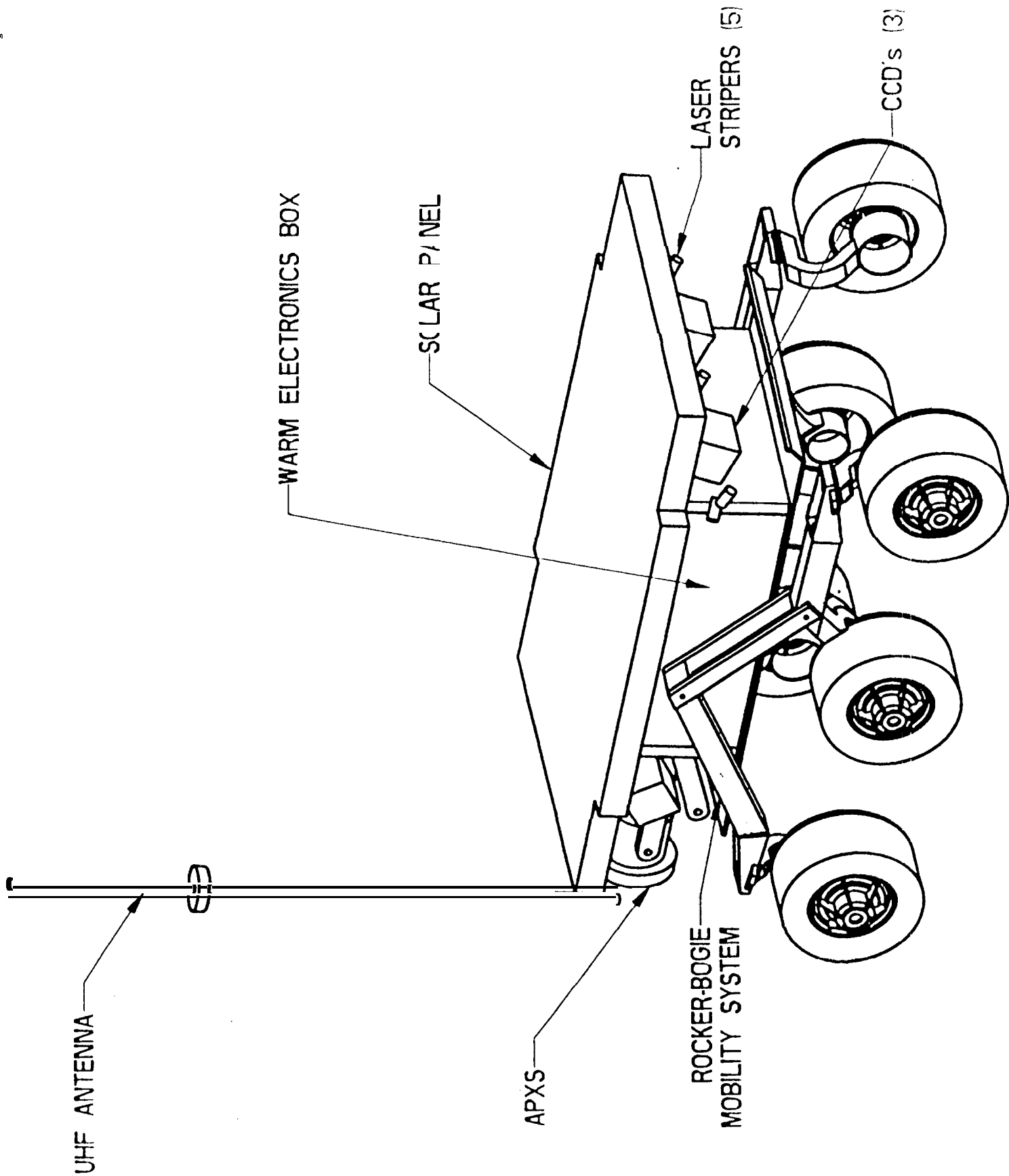


Figure 3. MESUR Pathfinder Microrover Schematic



Figure 4. MFSUR Pathfinder Landed Configuration